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# METHODS OF INVESTIGATING THE VESTIBULAR APPARATUS

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Parameters facilitating the characterization of the functional state of the vestibular apparatus were included in the physiological measurements following the discovery of vestibulo-vegetative and vestibulo-sensory disorders (294) in G. S. Titov's orbital flight. The vestibular apparatus is closely associated with numerous analyzers (kinesthetic, visual and auditory), and makes orientation in space possible with their participation. V. F. Undritz (303) discusses the following methods of investigating the vestibular apparatus: /246*

(1) a study of the sensitivity to adequate (acceleration) and inadequate (temperature and electricity) stimuli;

(2) an investigation of the condition of the vestibular analyzer under a certain load (as in rotation, for example);

(3) an evaluation of the reflex reactions accompanying the stimulation of the vestibular apparatus.

All the mentioned methods were used in the investigations that were carried out in space-flight conditions. A series of four special tests designed to facilitate the alternation of coordination and load tests was developed (295). These tests consisted in the evaluation of space orientation with

*Numbers given in margin indicate pagination in original foreign text.

closed and open eyes, with inclined head and body and finger-to-nose tests, and in the determination of the possibility of finely coordinated activity (writing and drawing with open and closed eyes).

The complex evaluation of all the other recorded parameters--electrocardiograms, respiration and electroencephalograms--was very important for the estimation of the reflex changes produced by the vestibular stimulations. Electrooculography was included in the telemetering program beginning with A. G. Nikolayev's flight.

Nystagmus is one of the constant reflex reactions of the striated muscles to the stimulation of the ampullar part of the vestibular analyzer. There are many methods of studying nystagmus (368, 305, 552, 654, 263 and 264). /247

The electrooculographic method (569, 383, 708, 546, 637, 110 and 709), which can also be used to record nystagmic oscillations, has recently been employed on a wide scale for such purposes. The changes in the potential differences produced by the movement of the eyeballs are recorded by the electrooculographic method. It is a known fact that the front pole of the eyeball is electropositive in relation to the rear one. The application of nonpolarizing electrodes in the area of the external and internal ocular angles would make it possible to record the changing potential difference produced by the eye movement to the right and left. The vertical movements of the eyeball can be recorded by attaching the electrodes to the upper and lower edges of the eye socket. Electrooculography in a space flight lasting many days involves considerable methodical differences.

For example, it is practically impossible to use nonpolarizing electrodes. With the elctrodes located at the above-mentioned points, it is impossible to insure an unfailing contact between the elctrodes and the skin. The method therefore had to be modernized, and a new method of recording electrooculograms in specific conditions developed.

Silver electrodes built into springy plastic inserts and securely attached to the helmet were used for recording electrooculograms in the first two flights. The electrodes were thus pressed against the skin in the cheek-bone area near the external angles of both eyes. The movement of the eyes to the right and left resulted in the appearance of bio-electric potentials, associated with the movement of the eyeball, as well as the action potentials of the facial and oculomotor muscles. The potential magnitude was 50 -100 microvolts. This called for the use of a preamplifier with an amplification factor of about 20. AC amplifiers were used, and the electrooculogram was therefore recorded as a first derivative, that is a speed-rate curve (494 and 709).

The electrooculograms recorded by the mentioned methods consist of several components reflecting the eye movement, blinking and the activity of the facial muscles. Nystagmus has a well pronounced typical appearance on the electrooculogram.

Eventually a method of recording electrooculograms was developed by means of detachable electrodes located near the external ocular angles and connected to the amplifiers by pushbutton-type connectors extended to the helmet (D. G. Maksimov). This method produces a better recording but requires a preliminary study and training on the part of the cosmonauts.

The electrooculographic method was used in four flights, and in the /248 last two of them (on the Voskhod-5 and Voskhod-6 space vehicles) it was combined with a seismo-cardiogram. The simultaneous recording of the two parameters with different frequency characteristics on one channel proved to be quite effective. There were no difficulties in analyzing the telemetric information. The amplitude of the seismo-cardiogram at the beginning of the flight was very low as the interelectrode resistance by-passed the seismic pickup. As the electrodes

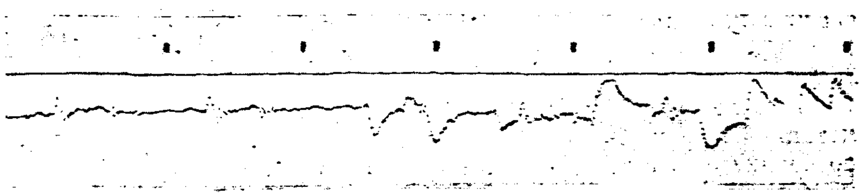

Figure 95. Facsimile of electrooculogram recorded during V. F. Bykovskiy's flight.

became a little drier, the interelectrode resistance gradually increased, as did the seismo-cardiogram amplitude, while the electrooculogram amplitude revealed a slight drop.

The electrooculographic data make it possible to evaluate the oculomotor reactions; oculomotor activity; the cosmonaut's vocal reactions; the control of the nystagmic reactions.

Different types of electrooculographic curves were plotted in the flight. Recording samples of single and group movements, muscular strain and nystagmic movements are shown in figure 95. Of particular interest is the oculomotor activity, which can be judged by the number of eye movements. Thus at the beginning of the flight Bykovskiy's eye movements ranged from 100 to 180 per minute, and by the end of the light they numbered 18-30 per minute. The vestibular tests are also clearly recorded on the electrooculogram.

The flights of the Vostok vehicles demonstrated the individual nature of the vestibular reactions during prolonged weightlessness. The manifestations of the vestibular reactions were also different. Vestibulo-sensory changes were predominant in the case of G. S. Titov, even though the vegetative functions revealed definite changes such as a pronounced pulse fluctuation, longer electromechanical retardations in the cardiac cycle, etc. P. R. Popovich revealed only illusions of position in the first minutes of weightlessness. A number of neurosomatic and vegetative changes were observed in V. V. Tereshokova who had no subjective complaints. The basic hypothesis currently used to explain the appearance of vestibulo-vegetative reactions in a state of weight- /249 lessness is the relative predominance of a pulsation from the vestibular analyzer produced by the reduced activity of the other afferent systems, particularly the diminishing pulsation from the proprioceptors (86). The increased activity of the vestibular centers may be conductive to a variety of reflex reactions. But there are also other opinions (180). The functional changes, for example, may be due to the relative cerebral hypoxia resulting from a possible diminution of the cardiac function. The interrelation between the cortex and subcortex, the type of higher nervous activity, the excitability of the subcortical centers and other factors apparently also play a certain part. The information obtained so far is still inadequate for the final evaluation of the mechanisms governing the vestibulo-vegetative changes in conditions of weightlessness. A further thorough investigation in this direction is required.

Electrooculography is undoubtedly an important method of determining the nystagmus and symmetry of eyeball movements in the course of vestibular tests, and the general oculomotor activity. A further improvement of this method should be sought in the following two directions: the improvement of the point of contact of the bioelectric potentials, and the development of appropriate functional tests. The simultaneous recording of horizontal and vertical eyeball movements, as well as a vectorial electrooculogram, deserves some attention.

Inadequate electrical irritations (281) are suggested for the investigation of the sensitivity of the vestibular apparatus, in addition to the adequate irritations (head movements). As is known, electrical irritation of the vestibular apparatus was used as a diagnostic test by B. B. Yegorov, the cosmonaut-physician, in the investigations carried out in the Voskhod space vehicle.

In addition to the eyeball movements, the investigations of the vestibular apparatus also take into account the body (754) and head movements. Special data units located in the cosmonaut's helmet (534) can be used for an objective recording of these movements. The above-described seismo-cardiographic pickup, attached to the head, can also be used for such purposes.

It would be expedient to develop multicomponent seismic pickups with separate sensitive elements for each perpendicualr direction.

Investigations of the head movements are important for both the precise implementation of the vestibular tests and the evaluation of the reflex reactions to the irritation of the vestibular analyzer. The methods of evaluating the other reflex reactions, somatic and vegetative, must also be improved. /250 It is a known fact that one of the manifestations of a vestibulo-somatic disorder is a disturbed coordination of movements. The special tests made during the Vostok flights were designed to evaluate the coordination of movements (294), and included writing tests consisting in tracing various geometrical figures with open and closed eyes. An analysis of the different vegetative reactions, pulse beat and body temperature (160, 161 and 182) is very important for estimating the condition of the vestibular apparatus. The effect of vestibular irritations on the electric stomach potentials was shown in some investigations (265).